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THE CARBONIFEROUS LIMESTONE IN CO. DUBLIN SOUTH OF THE RIVER LIFFEY.

By

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(Plates 5 and 6).

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I. Introduction.

The area dealt with in the present communication comprises that part of County Dublin south of the River Liffey and north of the Lower Palaeozoic strata and Caledonian granite of the Leinster Mountains (see map, Plate 6). From west to east it extends from County Kildare near Leixlip and Newcastle to the sea between Blackrock and the mouth of the Liffey at Dublin. A small portion of Co. Kildare west of Newcastle is also included. It is an area of low relief and elevation, and is deeply covered by glacial and later deposits towards its southern and eastern margins. Even where these are absent natural exposures of the Carboniferous rocks are few, and reliance has to be laid in large measure upon artificial openings such as quarries. Unfortunately many of these, open in the past, are now flooded, filled in, or otherwise unserviceable.

Sheets 111 and 112 of the one-inch Geological Survey map cover the area, and the relative Sheet Memoirs (Du Noyer 1860; Jukes and Du Noyer 1861) are the primary sources of information regarding the Carboniferous Limestone. The later official accounts (Hull 1875; Lamplugh and Others 1903) are essentially reprints of the 1861 memoir, so far as the Carboniferous rocks are concerned. A full bibliography by W. B. Wright up to 1902 is given in Lamplugh and Others (1903, pp. 148-155). Since then little has been published germane to the present investigation: a paper by Cole (1921) is important from the point of view of the pre-Carboniferous

history of the area; one by Lamont (1938) refers to certain details of Carboniferous sedimentation, and is, further, illustrated by an admirable map of the area of Sheets 102 and 112. The present writer, (Turner 1938, 1948) has published some notes on Co. Dublin Carboniferous which are relevant to the present paper.

Farther north, the basis of our knowledge of the Avonian succession in eastern Ireland was laid by Matley and Vaughan in their investigations of the Rush (Matley and Vaughan 1906) and Loughshinny (Matley and Vaughan 1908) coastal sections, and was supplemented and amplified by Smyth's work on Rush-Skerries (Smyth 1915) and Malahide (1920). These investigations have been summarised more recently (Smyth 1939; Smyth and Turner 1948).

Acknowledgements. The writer's thanks are due to the Director of the Geological Survey of Ireland and members of his staff for generous access to the original maps and records of their organization, which have supplied a mass of invaluable data from exposures no longer or but poorly visible, much of which is incorporated in the map (Pl. 6) accompanying this paper. To Dr. K. P. Oakley, Dr. A. Farrington, and Mr. D. I. Connolly, the writer is indebted for help in the field on various occasions. Dr. H. M. Muir-Wood, Dr. C. J. Stubblefield, Dr. Stanley Smith, and Mr. A. G. Davis, have given much assistance in palaeontological matters. But above all to Professor L. B. Smyth is the writer indebted for friendship and help: laboratory accommodation, palaeontological assistance, encouragement, and sympathetic patience, have all been given most generously.

II. Stratigraphy.

(*a*) *Historical.* In the course of the original mapping of Ireland, the Geological Survey attempted to delimit the following divisions of the Lower Carboniferous rocks throughout the country:—

5. Upper Limestone.
4. Middle Limestone or Calp.
3. Lower Limestone.
2. Lower Limestone Shales.
1. Basement Conglomerate or Upper Old Red Sandstone.

The tripartite division of the Carboniferous Limestone was readily affected in certain areas such as Sligo and Leitrim, but elsewhere, as in south-west Ireland and in Co. Dublin, great difficulties were encountered, and in the present area the Limestones were eventually grouped in a twofold arrangement of Lower and Middle-Upper Limestones. The classification was a purely lithological one, and the extensive palaeontological work of W. H. Baily, embodied in long lists of fossils in most of the Sheet Memoirs, did nothing towards facilitating its application, his concept of species being extremely wide even for the middle decades of last century. Thus in the Dublin memoir (Hull 1875, p. 18) we find a footnote to the effect that

Ellipsolithes ovatus Sowerby, *Goniatites carbonarius* Sow., *G. crenistria* Phill., *G. granosus* Portl., *G. obtusus* Phill., *G. spiralis* Phill., *G. truncatus* Phill., *G. subsulcatus* Brown, *G. undulatus* Brown, *G. intermedius* Brown, and *G. dorsalis* Brown are all synonyms of *Goniatites sphaericus* ! Were it possible to reinterpret his lists, admirably localised, in the light of modern palaeontological knowledge, a flood of light would be thrown on Irish stratigraphy. But by an evil stroke of fate the Geological Survey collections have been inaccessible for the past twenty years and more, and modern work on Irish Carboniferous stratigraphy has been largely centred on areas of extreme complexity, like Rush and Loughshinny, for which the Survey collections would be inadequate, even if accessible.

Nevertheless, despite the lack of a palaeontological method of attack upon the problems of Dublin stratigraphy, certain important advances were made by the original surveyors, and with few exceptions the Lower Limestones and combined Middle-Upper divisions were correctly recognized. The present investigation has shown no reason to alter the mapping in that respect. Du Noyer went still further; in the area of Sheet 111, he recognised a group of fossiliferous beds in the Upper Limestone around Peamount and Castle Bagot,—cherty, fetid, and full of fossils (1860. p. 21). These, it will be shown, are the representatives of the *Cyathaxonia* Beds of Rush-Skerries (Middle Viséan, S_2-D_1), and they have supplied the key to the interpretation of the structure of the area. Unfortunately, Jukes held them to be overlain by rocks similar to those beneath them and likewise mapped as Calp; in the upshot none of Du Noyer's division of the Middle-Upper Limestone was published, Jukes recording his " conviction of the very uncertain value of these hypothetical distinctions in the limestone of the district, resting as they do on mere lithological evidence, and being rather opposed than supported by stratigraphical grounds of reasoning." (Hull 1871, p. 51, footnote).

In another direction Du Noyer appears again to have had a deeper insight into the geology of our area than his chief. In Sheet 111 high horizons of the Carboniferous Limestone outcrop at several points between Rathcoole and Newcastle in close proximity to the Lower Palaeozoics to the south. They strike towards the boundary at a high angle, and Du Noyer (1860, p. 22) rightly claimed a faulted junction; but Jukes had developed a theory of an unconformable boundary, with the Leinster Massif remaining unsubmerged until far on in Carboniferous Limestone times, and in a footnote he wrote, " I do not think it at all necessary to suppose that there is a fault between the Carboniferous and the Lower Silurian, but simply a total unconformity between the two, and an overlap in the Carboniferous group." As will be seen in the sequel, the true explanation of the boundary-problem appears to combine the views of both Jukes and Du Noyer.

(*b*) *Basement Conglomerate and/or Old Red Sandstone.* West of Newcastle the Old Red Sandstone just enters the south-western extremity of this part of Co. Dublin, resting uncomformably upon the Lower Palaeozoic rocks, but is wholly concealed by Drift. The nearest exposures are in Lyons Demesne and on Boston Townland,* Co. Kildare (Du Noyer 1860, pp. 15-16). It is of no great thickness,

*Not to be confused with Boston Hill, on the north side of the Kildare Hills (Sheet 119).

about 150 feet, according to Du Noyer (*op. cit.* p. 7), and consists of quartz-conglomerate and grit, followed by red sandstones and shales.

At the south-east corner of the area there is a remarkable deposit on the coast at Blackrock, seen immediately north of the Swimming Bath, which unfortunately conceals its junction with the Leinster Granite to the south. It was first described briefly by H. J. Seymour (Lamplugh and Others, 1903, p. 12). It is a coarse, rudely stratified breccia, with boulders up to three feet in length consisting exclusively of granite, and set in a coarse, ill-sorted matrix of the same material. A thickness of some 12 feet, measured at right angles to the crude stratification which dips steeply northwards at angles of about 65°, is exposed before the breccia disappears under the shore-sand. Both the boulders and the matrix are quite unaltered, apart from a slight infiltration of carbonate, which is revealed by a moderate effervescence when treated with acid: the felspars are strikingly fresh. Some of the boulders are so sharply angular that it is easy to cut one's finger on their edges when extracting them from the matrix. There is no sign of cleavage or crushing of any kind.

The infiltrated carbonate suggests a derivation from the waters of the Dinantian sea, and the breccia appears to consist of granitic debris which has either accumulated practically *in situ* or has been transported as a mud-flow. How much of the steep dip is original, and how much due to tectonic disturbance is hard to say, but from the steep attitudes recorded for the Carboniferous limestones to the north it would seem that the breccia has been tilted strongly in post-Dinantian times. The freshness of its felspars and angularity of its fragments bespeak sedimentation under arid conditions. In view of the abundant plant and animal remains known from the Upper Old Red Sandstone of Ireland, it seems more likely to have been a hot than a cold climate.

(*c*) *Lower Limestone Shales.* Like the Old Red Sandstone, this division just enters Co. Dublin on the south-west corner of the area, but is not seen outside Co. Kildare, where about 150 ft. of impure limestones and shales outcrop from Lyons Demesne south-westwards (Du Noyer 1860, pp. 7, 16-17). They may well underlie the whole area, since they appear in the crest of the great Kildare Hills—Portrane anticline at Rathcoffey Hill, at Swords, and at Donabate. At Swords they are at least 800 feet thick, and of K-Z age (Turner, 1938, p. 26). There is room for a considerable thickness of them to the north of the Blackrock Breccia.

(*d*) *Lower Limestones.* These, likewise, just enter Co. Dublin from the south-west, being seen in Co. Kildare at Ardclough, where the writer has shown that they, like the Lower Limestones in general, are of C_1 age (Turner, 1948, p. 53). In the extreme south-east, these beds were once exposed in Blackrock Park and again farther north by the railway near Booterstown Station; these exposures are no longer visible, but a little may be gleaned from the manuscript maps of the Survey. In Blackrock Park dark grey limestone was exposed; at Booterstown, very compact grey limestone, striking due north and south, and nearly vertical, the dip being west at 78°. The facts are rather suggestive of a fault between the Limestone and the Granite to the south.

In the extreme north of the area the Lower Limestones appear in the crest of an anticline which is crossed by the Liffey at Hermitage Golf Course, east of Lucan. They are typical Upper Tournaisian (C_1) reef-limestones, and may be seen just inside the entrance to the Golf Course from the main road. There is a fine cliff-section in the right bank of the river, which reveals the highest beds of the Lower Limestones as importantly different from the subjacent C_1 limestones. They are dark, fine-grained limestones, with a fauna of cephalopods: the latter include *Merocanites subapplanatus* L. B. Smyth. Orthocone nautiloids also occur. These goniatite beds include a laminated deposit of alternate layers of carbonate of lime and carbonate of iron, and appear to be early Viséan (C_2) lagoonal deposits laid down upon the surface of the Tournaisian-reef limestones.

In the Hermitage cliff the beds are on the south-east flank of the anticlines: they reappear higher up-stream in the opposite flank in the grounds of Woodville, where *Kaypericyclus* cf. *kochi* (Holz.) occurs in the old quarries beside the river.

A confirmation of the dating of these goniatite-limestones is supplied by the lithology of the lowest beds of the overlying Calp, which are well seen a little downstream from Hermitage in the grounds of Quarryvale. At the Grotto, on the boundary between Quarryvale and Brooklawn, some 12 feet of hard thin-bedded dark limestones and shaly mudstones are exposed; they contain layers of limestone crowded with flakes of white mica, more like a flagstone than an ordinary limestone. These evidently represent some sudden influx of terrigenous material into the mid-Dinantian sea. Such an influx is suggested by the intercalation, at Rush and Skerries in the north of Co. Dublin, of the spectacular Rush and Lane Conglomerates, the product of violent disturbance in early Viséan times, perhaps of seismic nature. These can be found southwest of Rush at Kilsallagan and Lispopple, though not so strongly developed as on the coast. The micaceous limestones of the Grotto would seem to represent the finest sediment, settling far from its source at the beginning of Viséan, i.e. C_2, times. We shall see presently that analogous phenomena tended to recur in Middle Viséan times.

(*e*) *Calp* (*Lower Viséan*: C_2-S_1). This division of the Dinantian occupies much the largest part of our area, extending from the Liffey southwards to a little beyond the Grand Canal before it disappears under the overlying *Cyathaxonia* Beds. The finest exposures are in the gorge of the Liffey, immediately above Leixlip, but are unfortunately being concealed by the construction of a dam for a hydro-electric plant. The writer was able, however, to investigate not only the river section but also the excavations for the dam. The Calp was found to consist of a monotonous succession of dark, fine-grained limestones, interstratified at intervals of a foot or eighteen inches with dark, earthy shales and calcareous mudstones. The beds are almost entirely devoid of chert, and extremely unfossiliferous. Similar, though less extensive, exposures may be seen on the Canal at Gollierstown Bridge, where the rocks have been quarried, and on the outskirts of Dublin at Crumlin, where, however, most of the old quarries are now flooded. A very beautiful ornamental

lake has been formed in an old Calp quarry in the grounds of Turret House at Goldenbridge. The Calp is also worked extensively for making concrete and bricks at Moracrete Works, Crumlin. Some large quarries in the Calp within the limits of the city are now built over, e.g. on the south side of Brighton Square, where thick-bedded, earthy limestones and shales were seen in the original survey.

At Inchicore Transformer Station, Goldenbridge, a well was sunk in 1929, of which the following is the record, as preserved by the Geological Survey:—

Drift	55 ft.	6 ins.
Calp rock	8 ft.	10 ins.
Sandstone	1 ft.	2 ins.
Black limestone ...	14 ft.	
Dark grey limestone ...	20 ft.	6 ins.
	100 ft.	0 ins.

At Messrs. Guinness's brewery the Limestone was reached beneath 95 feet of drift, and was penetrated to a depth of 180 ft. At Crumlin Park athletic ground 96 feet of drift overlie 24 feet of limestones, while at Clarke's Factory, South Circular Road, black limestone occurred 9 feet below the surface. At Messrs. Judd Brothers' premises in Hendrick Street, close to the north bank of the Liffey between Collins Barracks and the Four Courts, a well sunk in 1920 gave the following record:—

Drift	62 ft.	8 ins.
Dark limestone ...	3 ft.	1 in.
Calp	232 ft.	
Grey limestone ...	2 ft.	5 ins.
	300 ft.	2 ins.

The deepest well in Dublin known to the writer was sunk by the Dublin Port Milling Co. at Alexandra Quay on the north bank of the river. Unfortunately its record is very defective, and even the total depth is uncertain, but beneath 124 feet of drift, the limestone was penetrated to considerably more than 1,400 feet. To a depth of 950 feet the record consists dominantly of blue limestone and blue shale. Next, grey beds appear and, below 1,000 feet, blue again; then below 1,190 feet the colour of the limestones and shales was grey to at least 1,260 feet, at which point the detailed record stops. Provisionally one may place the top of the Lower Limestones at 1,190 feet, giving a thickness for the Calp of at least 966 feet. This figure can be checked against the width of outcrop of the Calp, which between Hermitage and Clondalkin is 2½ miles wide at its narrowest. A thickness of 960 feet over that distance would require an average dip of only 4½ degrees, which is far below the angles actually observed; so the true thickness of the Calp is likely to be much higher.

A well sunk at Clonbarris Cottage, nearly 1,100 yards west of Clondalkin railway station, passed through 180 feet of thick and flinty limestones beneath 8 feet of Boulder Clay. More recently (1949) a well sunk by the Dublin Dairies at Kimmage penetrated dark limestones, with shaly partings and devoid of chert, to a depth of 135 feet.

The Calp is extremely poor in fossils, which apart from indeterminable plant debris and worm-tracks are confined to occasional crinoidal bands. The chief forms are brachiopods, and these are usually of small size. The following have been collected:—

Plant debris	1
Annelid burrows	1
Chonetes sp.	2
Dictyoclostus sp.	2
Echinoconchus cf. *punctatus* (Mart.)	4
Linoproductus sp.	4, 5
Plicochonetes crassistria (M'Coy) var *minima* (Paeck.)	5
Plicatifera carringtoniana (Dav.)	2
Schuchertella ? *sp.*	2
Spirifer sp. striatoid form	2
Spiriferellina perplicata (North)	3
Paraparchites inornatus (M'Coy)	2

Localities: 1, Moracrete Works Clay Pit, Crumlin (6-in. Dublin 18/3); 2, Small quarry at Sally House, Cooldrinagh Townland (17/1); 3, Branch of the Griffin River by the roadside, W.N.W. of Castle Bagot, Kilmactalway Townland (21/1); 4, North end of a trench close to west margin of Baldonnell Airfield, and west of Rock House, Baldonnell Upper Townland (21/1); 5, Mill-race opposite Avonbeg, Blue Bell Townland (18/3).

Baily (Hull, 1875, p. 15, 16-19) records plant stems, *Chonetes laguessiana*, and *Goniatites sphaericus* from his Locality 12, "Quarry near Blackhorse Bridge, Goldenbridge South Townland." The goniatite would be of great importance, could it be re-determined. Provisionally one may conjecture it to be either a *Munsteroceras* or a *Nautellipsites*.

The petrology of the Calp limestones of Dublin has been discussed by O'Reilly, who argued that their insoluble residues are of volcanic origin (O'Reilly 1897). Although the matter is still obscure, it may be pointed out that recent work on the Irish Dinantian has rendered O'Reilly's suggestion less improbable than when it was first propounded, for Ashby (1939, p. 324) dates the Lower Volcanic Group of Limerick (100 miles to the south-west) as early S_1, and unpublished work by the present writer suggests a similar age as likely for the Phillipstown Volcanics of Offaly (less than 40 miles to the west). Hence volcanic dust may well have fallen into the sterile sea in which the Calp accumulated.

(*e*) *Cyathaxonia-Beds* (Middle Viséan: S_2-D_1). The beds of this division with their characteristic seams of black chert, often abundant fossils, and, above all, their striking interruptions of the normal course of sedimentation, constitute the most interesting and, for elucidating the structure of the area, the most significant division of the Dinantian limestones. Owing to their more resistant character, they tend to develop topographic ridges where not obscured by drift; this is well seen east and south of Clondalkin as the Dublin-Cork highway climbs the Ashfield ridge, in which many large quarries were formerly worked. Two of these, between Monastery Road and St. Brigid's Cottages, are still actively exploited at the present

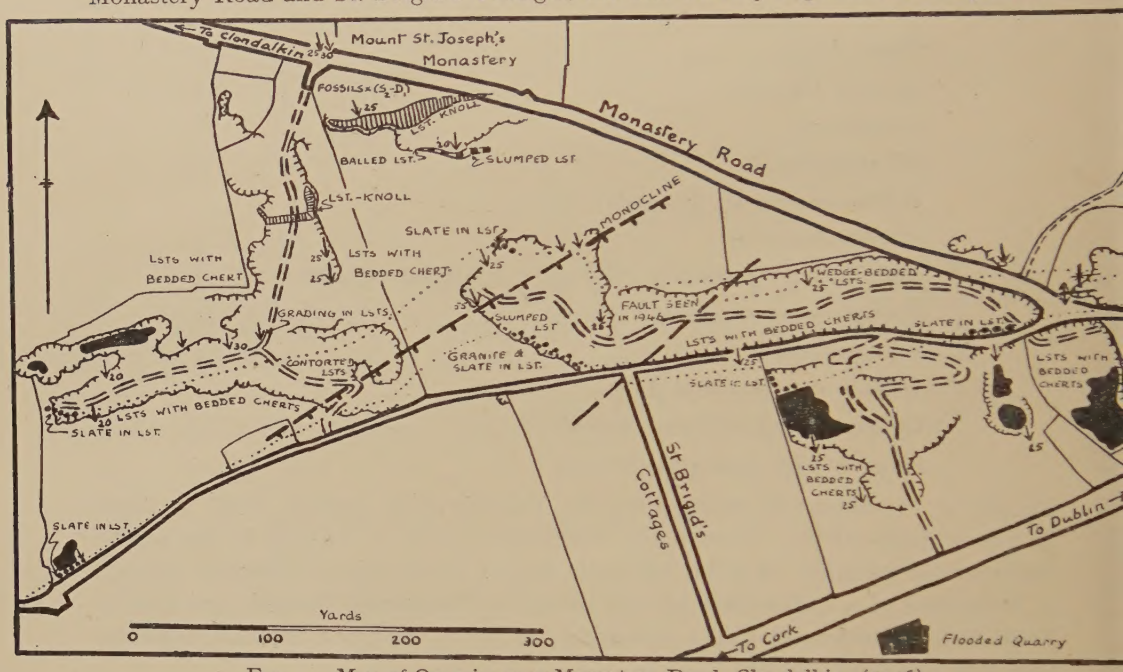

FIG. 1. Map of Quarries near Monastery Road, Clondalkin (1946).
(*Based on the Ordnance Survey by permission of the Minister for Finance*).

day (Fig. 1). A north-south fault, passing through Clondalkin, shifts the ridge southwards to the southern side of Newlands Golf Course, where it forms a conspicuous feature against the skyline, from both south and north.

The most easterly exposure of the *Cyathaxonia* Beds is in the River Dodder above Donnybrook Bridge. Formerly, they were worked extensively at Milltown, where there is a good section of typical cherty beds in the river above Milltown Bridge. They are again seen in the Dodder in small exposures at Rathfarnham Golf Course. In this eastern region they are very poorly fossiliferous, but when followed westwards from Terenure past Crumlin Cross-roads to the Ashfield ridge at Red Cow, beyond the Greenhills Esker, they gradually become more fossiliferous. Still farther west, around Castle Bagot and Corkagh, they include highly fossiliferous, dark, coarse, crinoidal limestone of *petit-granit* type, and reach the Lower Palaeozoic massif on the outskirts of Rathcoole. An outlier, cut off on the east

by a N.E.-S.W. fault, occurs around Peamount Sanatorium and Newcastle. It was in this area that their stratigraphic significance was first recognised by Du Noyer.

Lithologically, the *Cyathaxonia*-Beds resemble the underlying Calp in containing dark, fine-grained, unfossiliferous limestone and calcareous mudstone; such rocks are, however, associated with much dark, crinoidal limestone, which is often highly fossiliferous, and numerous seams of black chert, averaging some two inches in thickness. The beds were extensively quarried in the last century for rough stone, and the black chert seams are conspicuous in countless walls throughout the area. A typical section of the lower part of the *Cyathaxonia*-Beds was measured in the large quarry immediately north-west of Airfield House, Red Cow:—

Limestone	seen for 5 ft.
Limestone, with chert near top	4 ft.
Shale parting	1 in.
Limestone with two chert seams	4 ins.
Shale and limestone	4 ins.
Limestone with chert at base	2 ft. 8 ins.
Shale	1½ ins.
Limestone with chert at 2′ 8″ and 3′ 7″ above base	4 ft.
Limestone, shaley at top, with chert	2 ft. 8 ins.
Shale	2 ins.
Limestone with chert near top	2 ft. 10 ins.
Limestone, chert and shale	5 ft. 10 ins.
Limestone	2 ft. 6 ins.
Limestone with chert near top	5½ ins.
Shale	2 ins.
Crinoidal limestone with chert	9 ins.
Shale	1½ ins.
Limestone with chert 1″ above base	2 ft. 3 ins.
Crinoidal limestone with chert near base and top	1 ft. 9 ins.
Shale and limestone	7 ins.
Limestone with chert in lower half	7 ins.
Limestone and shale	5 ins.
Crinoidal limestone, with chert near base	3 ft. 8 ins.
Cherty limestone and shale	7 ins.
Limestone, chert at base	1 ft. 3 ins.
Massive limestone	1 ft. 4 ins.
Limestone with chert at top	1 ft. 8 ins.
Limestone with chert at top	3 ft. 9 ins.

The two highest members of this section are part of a series of more massive limestones, 25 ft. thick, seen in the southernmost part of the quarry.

The black chert seams are most often developed a little above or below the base or summit respectively of the limestone stratum in which they occur. Sometimes they exhibit excellent graded bedding; such is well seen in the central part of the large quarry north-west of St. Brigid's Cottages, Clondalkin; in the quarry at the limekilns due east of the Cottages; and in the roadside-ditch close to the boundary-fault on the outskirts of Rathcoole. The grading is due to sudden, short-lived influxes of crinoidal and shelly debris, with abundant foraminiferal tests, to the stiller water in which the finer-grained limestones were accumulating; the junction between the two is sharp and often irregular. As the disturbance died away, the organic debris settled, the heaviest and largest fragments first, the smaller and lighter more gradually, and there is thus a gradual passage upward into the more normal fine-grained limestone. The more porous character of the crinoidal debris has afforded a preferential medium for absorption of the colloids which have silicified. It may be mentioned that these graded cherts invariably "young" upwards.

The formation of the chert seems to have taken place penecontemporaneously with that of the individual limestone strata. No cases have been observed in either this or large surrounding areas of chert-veins definitely later than the tectonic movements which have affected the rocks, and an epigenetic origin can be dismissed. In many cases the chert does not occur exactly at the top or bottom of a limestone-stratum, but at one or two inches from either or both of the limits; it is much more common in beds of appreciable thickness than in the thinner partings or minor strata between them. This is suggestive of a penecontemporaneous origin, the silica being originally distributed throughout the mass of a stratum and becoming concentrated in a particular zone towards either top or bottom, or sometimes both. The comparative scarcity of cherts in thinner partings suggests that such concentration was effected in many cases before the deposition of the next stratum and that the rate of consolidation of the limestone was rapid relatively to that of accumulation of the whole sequence. Just why the chert should so often favour a position close to the inferior or superior limits of a stratum is obscure: in some cases, as already noted, it has been determined by porosity. Cox, Dean, and Gottschalk have shown that calcium carbonate solution saturated with carbon dioxide is a strong precipitant of silica gel from acid solution (Twenhofel 1939, p. 372), and it seems possible that a critical concentration of carbonic and other acids might arise from the decomposition of organic matter at a certain depth beneath the upper limit of a stratum in course of deposition, and so induce precipitation of silica. Such a precipitate might continue to grow for a time by incorporation of material separating at higher levels as the thickness of the stratum increased; in this way the occurrence of the lower chert seams and the impoverished intervals between upper and lower might be accounted for. The upper seams postulate a restarting of the process—a periodic affair which may be paralleled with

the periodicity of the sedimentation itself. It must be emphasised that the vertical distribution of the chert seams is far from high in regularity, but is sufficiently so to suggest that some such broad principle underlies it.

A second feature of the *Cyathaxonia*-Beds is the presence of lenticular, knoll-like masses of unbedded limestone interstratified with the cherty limestones. The best-exposed example is seen in the quarry N.W. of St. Brigid's Cottages, 100 yards from the entrance on Monastery Road (Pl. 5, A). The cherty limestones above and below the knoll dip southwards at 25°; measured across the strike, the knoll is at least 85 feet wide and 15 feet high; it can be seen for 100 feet along the strike. Its upper surface is markedly convex. It consists of fine-grained, light grey limestone, in which the only noticeable fossils are small, sparsely scattered crinoid-ossicles. A curved streaky banding is visible on moderately weathered surfaces of the quarried rock, and I am indebted to Dr. K. P. Oakley for the suggestion that this may indicate that some form of algal activity may have produced the mound of unstratified limestone. If this be the case, it would suggest that the *Cyathaxonia* Beds were formed in fairly shallow water, if we are to accept Twenhofel's estimate of about 80 metres as the lower limiting depth of much carbonate precipitation by photosynthesis (1939, p. 333). A second knoll is seen in the lower part of the old adjacent quarry in front of Mount St. Joseph's Monastery: it is exposed along the strike for about 300 feet and attains a maximum thickness of 12 feet. In section these knolls differ from the far larger ones figured by Parkinson from Clitheroe (1926, fig. 2) in their much smaller thickness as compared with width, and in having flat instead of convex bases.

A still more striking feature of the *Cyathaxonia* Beds is their occasional development of large-scale wedge-bedding. This is well seen in the range of large quarries which extends from the " Red Cow " inn to Monastery Road, particularly at the west end of the large quarry in front of the " Red Cow " and through the greater part of the quarry north of St. Brigid's Cottages, especially the northern face (Pl. 5, B). Still farther west it is well developed on Bedlesshill Townland, at the back of the second quarry east of Corkagh House Lodge. There is reason to think that it may have been well developed in some of the quarries—now flooded or filled-in—at this horizon around Crumlin and in the Dodder valley. In these wedge-bedded limestones it is impossible to follow any single stratum far, partings may dip in the opposite direction to their neighbours, and individual beds die out with great rapidity. The phenomenon is eloquent of interruption of the normal course of sedimentation, and is found over a considerable area.

This is confirmed by the appearance around Clondalkin of recumbent folds in the *Cyathaxonia* Beds, formed contemporaneously with the course of sedimentation, and indicating subaqueous gliding of the sea-floor, always, be it noted, from the south. The brow of one of these is exposed in the face of a small, flooded quarry, 200 yards south-west of the Red Cow Inn, the beds dipping southwards at 30°. Although the upper and lower limbs of the fold are approximately parallel, the beds do not appear to have suffered brecciation, but are greatly thickened in the brow of

the fold. Unfortunately, the quarry face is considerably obscured by vegetation, but in the old quarry, two-thirds of a mile to the west, in front of St. Joseph's Monastery, exposures are clearer and more extensive (Pl. 5, C). The quarry face, for some 40 yards, shows the following section, the beds dipping southwards at 20°:

5. Crinoidal limestone, 2 ft.
4. Limestone folded recumbently, the upper beds thin-bedded, the lower more massive, 14 ft. 6 ins.
3. Bedded limestones with cherts, 7 ft.
2. Massive ill-bedded limestone, 11 ft.
1. Evenly bedded limestone, seen for 4 ft.

Here again, the upper and lower limbs of the fold are approximately parallel, and there is great thickening in the brow. The brow is seen to end westwards, and the place of the fold in the sequence to be taken by a thick massive stratum in which great pillow-like masses of limestone are enclosed.

That the recumbent structure is one formed contemporaneously with the deposition of the strata, and not by later tectonic movements, is established by the relation between the crinoidal limestone at the top of the measured section to the underlying beds, since it rests transgressively upon them and cuts out about a foot of the underlying beds near the east end of the face.

A third example was seen in 1946-48 at the west end of the great quarry behind St. Brigid's Cottages, where a thin bed of massive limestone was completely doubled back upon itself. Since, however, this particular example is cut by a small fault with associated calcite veins the possibility of its being due to subsequent tectonic displacement is considerable.

Similar features have been observed in the black, cherty limestone so well exposed in the large quarries at Castle Carbury in the west of Co. Kildare, near Edenderry. These appear to be about the same age as the *Cyathaxonia* Beds of Co. Dublin. They were described by Du Noyer as follows (1860, p. 17):

"Directly under the old castle, a large quarry exposes a vertical section in these beds to the depth of about thirty-five feet, the lowest beds exposed being evenly deposited, with a tendency to become flaggy. After the formation of these beds, a trench appears to have been eroded, deepening a slight local depression in them. When the process of deposition was renewed, the calcareous mud was piled in an irregular manner into this cavity from all sides, eventually filling it up, and restoring to the sea bottom, at this particular locality, its original flatness, when the normal regularity of deposition of the calcareous mud was once more resumed. At the south west end of this quarry, the beds again lose their evenness of deposition, and become lumpy and irregular, and have been subjected to a small amount of contortion."

The quarry has been considerably enlarged since du Noyer's time, and shows marked recumbent folding as well as the features described by him. When the plane of section is approximately parallel to the strike of the fold, it often becomes difficult to distinguish between the latter and large scale wedge-bedding, and it is very likely that some of the examples of the latter seen around Clondalkin and farther west are really recumbent folds produced contemporaneously with the course of sedimentation by subaqueous sliding, and exposed in sections more or less along the strike.

The occurrence of fragments and boulders of granite and other rocks, derived from the Leinster Massif, in the Carboniferous Limestone of this area has long been known; the exotic material all occurs in the *Cyathaxonia* Beds (Fig. 2, p. 188). First recorded by Haughton, later discoveries were made by the Geological Survey and Montgomery. The known occurrences range from Donnybrook through Milltown and Rathfarnham to Crumlin and Red Cow. Slate fragments were recorded by the Survey at the east end of the large quarry north of St. Brigid's Cottages, near Red Cow, and in 1946 Professor L. B. Smyth observed loose blocks of limestone with large granite fragments at the west end of the same quarry. They were located *in situ* by the writer, half way up the quarry face, which presented the following section:

Bedded limestone with cherts	2 ft.	9 ins.
Massive fine-grained and crinoidal limestones: from 7 to 14½ ft. above base with abundant small, angular fragments, and larger pieces of granite, slate, schist, and volcanic ash, together with large scattered crinoid-ossicles, cyathaxonid and zaphrentid corals, *Syringopora,* and presenting cross-sections of bellerophontids and productids. In the lower part occasional chips of slate occur with phaceloid *Lithostrotion.* Chert is absent throughout	20 ft.	2 ins.
Well-bedded limestones with shaly partings and occasional seams of chert	10 ft.	7 ins.
Bedded limestones without chert	8 ft.	
Massive irregularly bedded limestones	33 ft.	
Well-bedded limestones	16 ft.	
Shaly limestones with chert	1 ft.	2 ins.
Dark massive limestones with scattered crinoid ossicles and a few small fragments of slate	7 ft.	

This section was measured in 1946, since when the quarry has been extended with consequent alteration of the face.

The main horizon of exotic fragments strikes W.S.W. to a small flooded quarry on the north side of the lane leading to Clondalkin, where the following section is seen:

Dark fine-grained limestone	6 ft.
Very coarse crinoidal rock, full of angular fragments of slate and grit, many of them decomposed and limonitic (*Emmonsia parasitica* was found here)	6 ins.
Dark fine-grained limestone	2 ft.

Fragments of slate, etc., have been found farther east, near Greenhills, in an old quarry on Kilnamanagh Townland, W.N.W. of Constantine House, which showed the following section:

Well bedded, fine-grained limestones with chert seams and lenticles	8 ft.
Gap	25 ft.
Massive limestone with 3″ cherty bed at base Dolomitic crinoidal limestone, with abundant phaceloid *Lithostrotion*	
Gap	about 15 ft.
Massive fine-grained limestone Fossiliferous crinoidal limestone with *Fasciculophyllum* and productids, and numerous small angular fragments of slate and volcanic rock	9 ins.
Massive fine-grained limestone.	

Granite fragments were also found west of Clondalkin in the lane leading to the quarry on Bedlesshill Townland to which reference has already been made (p. 179).

The concurrence in the *Cyathaxonia* Limestones of subaqueous sliding from the south and fragments of Leinster granite, etc., many thousand feet above the base of the Carboniferous Limestone indicates a powerful uplift of the Leinster Massif in mid-Viséan times. There is nothing in the beds apart from the exotic fragments to indicate proximity to a shore-line, and the occurrence of fragments up to 6 and 8 inches in length requires some special agent of introduction. Floating ice can be ruled out, on the ground that no evidence of glacial action is known in Europe in Lower Carboniferous times. Jukes favoured the view that the granite, etc., had been transported adherent to the roots of floating plants, but there is no sign of plant remains in the rocks. The writer therefore favours a tectonic origin, the Leinster Massif having been elevated abruptly by faulting along its northern margin. This will also explain the slump-folds, which appear to have travelled northwards. Such an origin would be quite comparable to that of the well-known Tiddeman Breccia of the Skipton Anticline in West Yorkshire, which is likewise of Middle Viséan age.

The following fossils have been identified from the *Cyathaxonia* Limestones:

Calcisphaera sp. 16, 19.
Koninckopora sp. 4, 17, 19.
Agathammina pusilla (Geinitz) 4, 18, 19.
Ammovertella sp. nov. 18.
Archaediscus karreri Brady 4, 16, 18, 19.
Climacammina antiqua Brady 19.
Cribrostomum sp. 4, 18, 20.
Endothyra ammonoides Brady 17.
,, *bowmanni* (Phill.) 4, 17, 18, 20, 21.
,, *ornata* Brady 17, 18.
,, *spp.* 4, 19, 21.
Globovalvulina bulloides (Brady) 20.
Glomospira gordualis (Jones & Parker) 20.
,, *sp.* 4, 19.
Nodosaroum sp. 18, 20.
Rectocornuspira sp. 16, 17.
Stacheia pupoides Brady, var *compressa* Brady 20.
,, *sp.* 4, 17, 18, 19.
Tetraxis decurrens (Brady) 20.
,, *palaeotrochus* (Ehrenberg) 20.
,, *sp.* 18, 19.
Trochammina sp. 4.
Valvulinella youngi (Brady) 20.
Caninia aff. *benburbensis* Lewis 4.
Cyathaxonia rushiana Vaughan 4.
Emmonsia parasitica (Phill.) 18.
Cf. *Fasciculophyllum carruthersi* Hudson 4.
Lithostrotion sp. 4.
Syrinopora sp. 4.
Fenestella sp. 14.
Fistulipora incrustans (Phill.) 17.
Athyris planosulcata (Phill.) 1, 6.
Avonia sp. 6.
Buxtonia sp. 2.
Camarotoechia sp. 1.
Chonetes laguessiana de Koninck 2, 7, 8, 10, 11, 12.
,, aff. *variolatus* d'Orbigny 8.
,, *sp.* 1, 2, 5, 7, 9, 15.

Composita sp. 13.
Daviesiella sp. 8.
Dictyoclostus sp. 6, 7, 9.
Echinoconchus venustus Thomas 6.
,, cf. *elegans* Thomas 7.
,, *punctatus* Phill. 10.
Krotovia aculeata (Martin) 7.
,, *spinulosa* (J. de C. Sow.) 2, 6, 9.
,, *thomasi* Paeckelmann 6.
Leptaena analoga Phill. 8.
Linoproductus sp. 1, 2, 5, 6, 8, 9, 10, 12.
Orthotetid 9.
Plicatifera carringtoniana (Davidson) 7, 12.
,, *plicatilis* (J. Sowerby) 2.
Productina margaritacea (Phill.) 8, 12.
Pustula sp. 4, 6.
Reticularia sp. 6.
Rhipidomella sp. 3.
Spirifer semicircularis Phill. 6.
,, *sp.* 6.
Bellerophontids 4.
Michelinoceras sp. 7.
Cummingella sp. 7.
Phillibole cf. *polteni* (H. Woodward) 12.
Ostracods 13, 19.

Localities:

1. Field north of Peamount Sanatorium, Loughtown Upper Townland (6. in. Dublin 17/3).

2. Old quarry opposite Mount St. Joseph's Monastery, Clondalkin (21/2).

3. First quarry east of St. Brigid's Cottages, Bushelloaf Townland, Clondalkin (21/2).

4. Quarry immediately north of St. Brigid's Cottages, Red Cow Townland, Clondalkin (21/2).

5. Quarry east of Corkagh House Lodge, Bedlesshill Townland (21/2).

6. By lane from Corkagh to Baldonnell, Brownbarn Townland (21/2).

7. Old quarry west of Belle Vue, Belgard Townland (21/2).

8. Old quarry south-east of Ardsolus, Brownbarn Townland (21/2).

9. Old quarry north of Greenhills, Kilnamanagh Townland (22/1).

10. First quarry south-west of Crumlin Cross-roads, Crumlin Townland (22/1).

11. Right hand bank of River Dodder, Rathfarnham Golf-course, northwest of Butterfield House, Butterfield Townland (22/1).

12. Old quarry west of Limekiln Farm, Greenhills Townland (22/1).

13. Old quarry by windmill, east of Crumlin Cross-roads, Crumlin Townland (22/1).

14. Right hand bank of River Dodder, opposite first weir above Donnybrook Bridge, Rochet Townland (22/2).

15. Old quarry in north-east corner of Fortunestown Townland (21/4).

16. Old quarry immediately west of Limekiln Farm, Greenhills Townland (22/1).

17. Quarry south-west of Mount St. Joseph's Monastery, Clondalkin Townland (21/2).

18. Small quarry west of St. Brigid's Cottages by lane to Clondalkin, Clondalkin Townland (21/2).

19. At side of Dublin-Cork road, Rathcoole, 150 yds. E.N.E. of Rathcoole House Lodge, Rathcoole Townland (21/1).

20. South bank of River Liffey, at the Grotto, Quarryvale Townland (17/2).

(*f*) *Ballymount Reef-Limestone* (*Middle Viséan—D_1* ?). The strata overlying the *Cyathaxonia* Beds are rarely exposed, and little can be said about them. At Ballymount Castle, due south of the Red Cow inn, a very small exposure of massive, grey, crinoidal limestone of reef type is seen by a pond. It yielded a number of brachiopods, including the following:

Brachthyris sp.—pinguis-group.
Gigantella aff. *latissima* (J. Sowerby).
Plicatifera plicatilis (J. Sowerby).
Schizophoria sp.

This faunule suggests an horizon in zone D, the limestone being analogous to that of Milverton in North Dublin (Turner 1938, p. 29).

(*g*) *Posidonomya-Limestones* (*Upper Viséan—D_2*). Still higher beds are present to the south-west, in a number of quarries around Kilnamanagh House and St. Columbs. They are dense, often siliceous, dark laminated limestones in thicker and thinner beds with earthly shale partings. The best exposure is seen in the old quarry in the garden at St. Columbs, where 30 feet of beds are visable, traversed by close-set joints which cause the rock to break into rhomboidal parallelopipeds. Baily records *Posidonomya becheri* from a quarry 200 yards E.S.E. of Kilnamanagh House, and the writer has found this lamellibranch in another, smaller quarry in the fields 350 yards south of that house. The rocks agree closely in lithology with

the *Posidonomya*-Limestones of Loughshinny. At Urney Chocolate Factory, Tallaght, black limestones were penetrated for 73 ft. beneath 23 ft. of Boulder Clay; they probably belong to this horizon.

These are the highest rocks observed in southern Co. Dublin. Whether the succeeding *Posidonomya* Shales of North Dublin are present in the heavily drift-covered ground along the foot of the Leinster massif, is quite unknown.

III. Structure.

In general terms, the present area occupies a basin, closed on three sides, but open to the west. The southern boundary is formed by the uplift of pre-Carboniferous rocks of the Leinster Mountains, which must extend north-eastwards under Dublin Bay to their detached outcrop on Howth to supply the eastern limit of the basin. The northern boundary lies beyond the Liffey, in the axis of the Kildare-Portrane Anticline; this runs north-eastwards through the Rathcoffey Inlier of Lower Limestone Shales, past Maynooth to Clonee, and thence to the south-west end of the Swords-Portrane Inlier of Lower Limestone Shales and older rocks. A subsidiary anticlinal axis brings up the Lower Limestones from Blanchardstown south-westwards to the Liffey, and enters the area of this paper south of the river at Hermitage.

The predominant strike of the rocks south of the Liffey is east and west. This strike is, however, interrupted locally by minor flexures ranging between N.-S. and N.E.-S.W. in trend, and by faults. At the present time the clearest demonstration of this is to be seen around the Red Cow inn, east of Clondalkin, where the east-west strike of the *Cyathaxonia* Beds can be followed through the many quarries as it swings round through N.W.-S.E. to N.E.-S.W. and is cut by faults with N.E.-S.W. trend. The latter are no longer actually visible behind the inn, but two parallel dislocations were seen during the present investigation: one in the large quarry immediately N.E. of St. Brigid's Cottages, the other in temporary excavations on the southern outskirts of Clondalkin, near Newlands Corner. The N.-S. fault postulated as passing through Clondalkin can be located by the intense dolomitisation of the limestones in a small quarry on Newlands Golf-Course, and the same phenomenon is to be seen in the Dodder by Rathfarnham Golf-Course. The remaining faults shown on the map are required by the areal distribution of the formations, and no great precision is claimed for their locations. Probably there are numerous other minor dislocations concealed beneath the drift and soil.

Throughout that part of the area lying west of a line drawn from Lucan to Saggart the strike is dominantly between N.E.-S.W. and N.-S., notably between Rathcoole and Newcastle, where alone can we observe the Carboniferous rocks in proximity to the Leinster Massif. Since the structures here run N.N.E.-S.S.W., Du Noyer's claim that the junction is a faulted one is amply justified, and is confirmed by the fact that the boundary between the Calp and *Cyathaxonia* Beds

strikes nearly at right angles to the boundary of the Massif. The repetition of the Calp-*Cyathaxonia* boundary is attributed to a strike-fault, otherwise the *Cyathaxonia*-Beds would both under and overlie the Calp at Peamount. A further confirmation of a faulted boundary to the Leinster Massif in this quarter is supplied by the character of the *Cyathaxonia*-Beds on the outskirts of Rathcoole, where seen in close proximity to the Lower Palaeozoic strata. Here, if anywhere, they should exhibit a littoral facies, if Jukes's theory of an unconformable boundary be correct, but they prove entirely devoid of any such features, and the only evidence supporting Jukes's theory—the presence of granite, etc. in the *Cyathaxonia* Beds—is found at distances up to four miles away from the older rocks.

That the same faulted boundary is present in the eastern part of the area, where surface evidence is utterly lacking, save on the coast, is suggested by the results of two wells drilled of recent years at Hazelbank Farm, on Whitehall Townland, Rathfarnham:

No. 1. 400 yards north of granite-limestone boundary.

Boulder Clay, 67 ft.

Black Limestone, 73 ft.

Limestone and chert, 16 ft.

No. 2. 90 yards south-south-east of No. 1.

Boulder Clay, 63 ft.

Black limestone, 32 ft.

Hard grey limestone, 33 ft.

Black limestone, 7 ft.

Micaceous magnesian limestone, 70 ft.

Hard blue limestone, 45 ft.

Here, within a few hundred yards of the granite, the Carboniferous Limestone was penetrated for 187 ft., without any indication of having been deposited close to a shore-line. The presence of chert in No. 1 well is suggestive that we are dealing with the *Cyathaxonia* Beds. The evidence is small, but is at least consistent with what is seen in the nearest exposures, in the Dodder. The structure of the valley of that river has been deduced on the assumption that the top of the *Cyathaxonia* Beds was reached in No. 1 well at 140 ft.

On this interpretation a faulted syncline extends along the Dodder, from near Tallaght to Milltown. Sollas (1893, pl. iv) indicated an anticline with similar trend in this position. Much depends on the relation of the boulder-bearing *Cyathaxonia* Beds at Milltown and Donnybrook to those at Crumlin, but their presence in the Dodder at Rathfarnham is definitely associated with faulting, and seems to favour the interpretation here adopted. The scarcity of evidence in Rathmines and Terenure is particularly regrettable.

It will be observed that the N.-S. fault through Clondalkin is represented as shifting the Carboniferous—Lower Palaeozoic boundary south of Tallaght (Fig. 2). Hereabouts the boundary is completely hidden by thick drift and alluvial deposits, but the topography is at least not inconsistent with the interpretation here advanced. An indirect piece of evidence from the older rocks seems to substantiate the presence in them of the fault. The Lower Palaeozoic slates are heavily intruded by igneous rocks which have been folded along with the slates, and attain their maximum and most continuous areal development south of Saggart. This lies to the west of the fault, and to the east there are only numerous small outcrops in the crests of anticlines. These minor outcrops probably represent exposures of the topmost portions of a larger body of igneous rocks at depth, as yet only revealed by denudation to a minor extent. They lie on the downthrow side of the postulated extension of the fault, and if originally continuous with the larger body west of the fault, demonstrate the existence of the latter within the Lower Palaeozoic rocks.

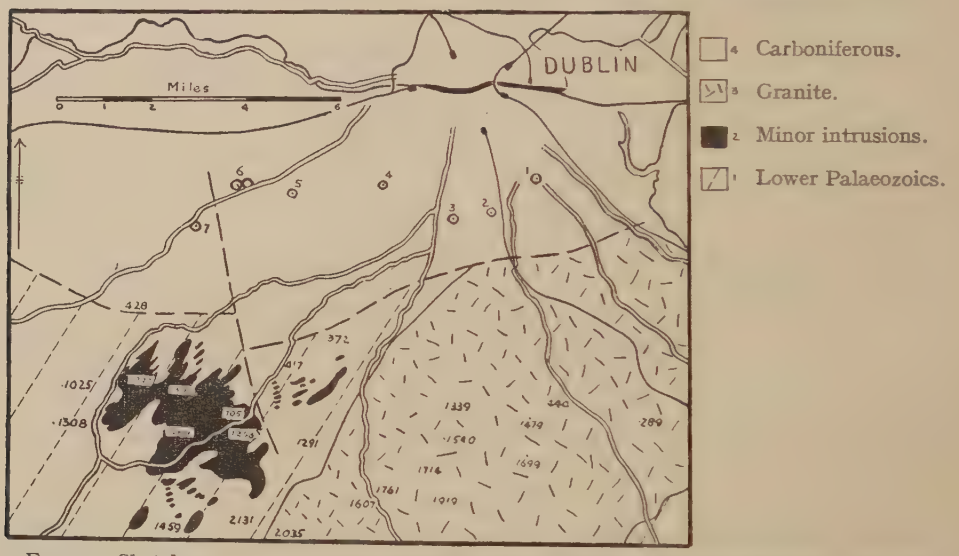

FIG. 2. Sketch-map of Co. Dublin South of the R. Liffey to show relation of Saggart minor intrusions to Clondalkin—Glenasmole Fault. Localities of granite, etc., in Carboniferous Limestone: 1. Donnybrook; 2. Milltown; 3. Rathfarnham; 4. Crumlin; 5. Greenhills; 6. Monastery Road Quarries, Clondalkin; 7. Corkagh.

(*Based on the Ordnance Survey by permission of the Minister for Finance*).

IV. PALAEOGEOGRAPHY.

It is generally considered that the Leinster Massif was mainly an upland area during Carboniferous times, constituting the western end of Jukes-Browne's St. George's Land, which extended eastwards to include much of Wales with prolongations into the English Midlands. Until the whole of the outcrops around the Massif have been examined, it will not be possible to speak positively on the validity of this concept in its application to Irish palaeogeography, but the present paper covers the whole northern border of the Massif, and the writer has also been able to examine some parts of the western margin.

Commencing in the south, the narrow strip of Carboniferous Limestone which extends south-westwards from Wexford Harbour to the Atlantic coast in Ballyteige Bay is of great importance, for according to Kinahan (1879, p. 12), " the shore-beds (light-coloured conglomerates, sandstones, shales, and clayrocks) are best developed to the northward and westward of the tracts of Carboniferous rocks, while to the southward they occur as subordinate beds, in the dark coloured shaly limestones, showing that the principal driftage in the Carboniferous sea was from the north, southward." Such lateral change in lithology would, if substantiated, go far to establishing the existence of land to northward in Lower Carboniferous times, and was accepted as such by Jukes-Browne (1911, p. 139). There seems, however, little ground for the further conclusion that the Carboniferous beds of this area occupy a high horizon in the Limestone Series. Baily specifically states (in Kinahan 1879, p. 59) that the Limestone " is evidently the Lower Limestone and Shale, similar to that which is so fossiliferous at Hook Head." Professor Smyth (1939, p. 311) has shown that the Hook sequence does not extend above C_2, and, though it is quite possible that higher beds may be present to the east, the bulk of species listed by Baily are clearly Hook forms. It is, however, significant that no Upper Old Red Sandstone, such as invariably underlies the Lower Limestone Shales from Hook westwards and north-westwards, is present, and it is quite possible that the Carboniferous sea may not have reached this easternmost area until Z-times. At Hook, fish-beds are particularly abundant in K_2, but the only records of fish-remains from the Wexford area almost certainly refer to beds of later age.

West and north of Hook the writer has studied the lowest beds of the Carboniferous Limestone in the River Suir at Granny Castle, above Waterford, and farther north in the latitude of Kiltorcan. The evidence so far obtained indicates that the base of the Lower Limestone Shales is somewhere in zone K. Not until we reach the neighbourhood of Goresbridge, nearly 30 miles north of Waterford, are the Lower Limestone Shales overlapped by the Carboniferous Limestone, and northwards from here to Kill, a distance of some 45 miles, the Lower Limestone is believed to rest directly on the Lower Palaeozoics and granite. Beyond Kill, at the south-western extremity of the area dealt with in this paper, the Lower Limestone Shales and Old Red reappear.

So far, then, as the scanty available evidence goes, we have reason to suppose that the western margin of the Massif between Kill and Goresbridge may have remained unsubmerged until Upper Tournaisian times (C_1) but the portions to north and south were submerged in K times. It is quite likely that the central parts of the Leinster Massif may have remained unsubmerged throughout Lower Carboniferous times, and it is perhaps significant that the Coalfield of the Castlecomer Plateau lies opposite this portion of the Massif, while unpublished work by the writer has failed to discover any sign of beds older than Z_2 around the Lower Palaeozoic inlier of the Kildare Hills, which is well south of the latitude of Kill. A determination of the age of the base of the Carboniferous around the still more westerly inliers of the Slieve Bloom and Devil's Bit mountains might throw light upon the westerly limit of this early Carboniferous land-mass.

In denying the faulted character of the northern boundary of the Leinster Massif, Jukes was largely influenced by the exotic material in the Limestone of the Dodder Valley and Crumlin, but since these have now been shown to occur in Middle Viséan rocks, they can have no bearing upon the question of Tournaisian geography. He also considered that the Howth promontory remained unsubmerged for a considerable time, but the boundary between the Limestone and the Cambrian rocks is very probably faulted there, and no littoral facies is developed in the former.

We may conclude, therefore, that the Lower Limestone Shales of the Swords and Rathcoffey Inliers, and the succeeding Lower Limestones underlie practically the whole of the area of the present paper and originally extended for some distance southwards. The highly fossiliferous reef facies of the Lower Limestone north of the Liffey and Tolka, with its abundant fauna of molluscs, brachiopods, and bryozoa is possibly replaced southwards by zaphrentid-phase limestones constituting a back-reef facies, similar to that of Malahide, or it may continue unchanged up to the southern limit of the area. At the end of Tournaisian times, powerful orogenic movements affected the region of North Co. Dublin, with the production of the Rush-Lane Conglomerates. To the south, however, a deepening of the sea led to the deposition of the Calp, the finer debris carried by the tsunamis from the north reaching the northern margin of the area. The Lower Viséan sea seems to have been mainly inimical to life except annelids, whose tracks and burrows are not uncommon, for such brachiopods as occur are small and stunted. Incessant fluctuations between more argillaceous and more calcareous deposition were persistent throughout the deposition of the dark limestones, calcareous mudstones, and earthy shales of the Calp.

In Middle Viséan times, brachiopods, crinoids and to a lesser extent cup-corals and trilobites, returned to the area in large numbers, especially in the west, and the concentration of silica in the water rose sufficiently to allow of precipitation of numerous chert bands. This seems to have been accompanied by shallowing of the sea, sometimes to a depth allowing operation of photosynthetic processes in marine algae. This shallowing was accompanied by strong movement of the boundary-fault of the Leinster Massif to permit exposure of the sub-Carboniferous floor of granite, schist and slate, boulders of which were carried northwards for at least four miles by tsunamis. At the same time the sea-floor at the foot of the fault-scarp was tilted northward, and became affected by sliding and gliding, with the production of small-scale recumbent folds which travelled downhill.

The Upper Viséan, on the other hand, was a period of quiescence and witnessed a return of conditions in many ways similar to those of the Calp sea, as the *Posidonomya*-Limestones accumulated. Thin-shelled lamellibranchs and occasional brachiopods were the commonest forms of marine life. Probably the Lower Carboniferous closed with the deposition of the argillaceous facies of the Posidonomya-Shales, but in the absence of these and of any Namurian deposits, it is not possible to say whether the powerful orogenic disturbances which occurred at this time in North Dublin played a part in the production of the structures affecting the Lower Carboniferous of our area.

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Explanation of Plates.

Plate 5.

A. Knoll of unbedded, light-grey limestone in dark, cherty, thin-bedded *Cyathaxonia*-limestones. Quarry south-west of Mount St. Joseph Monastery, Clondalkin.

B. Wedge-bedded *Cyathaxonia*-limestones, east end of quarry north of St. Brigid's Cottages, Clondalkin.

C. Contemporaneous slump-folding in *Cyathaxonia*-limestones. Quarry opposite Mount St. Joseph's Monastery, Clondalkin. Note the transgressive contact opposite the arrow at the upper limit of the thick bed in the upper half of the section. This thick bed is folded recumbently.

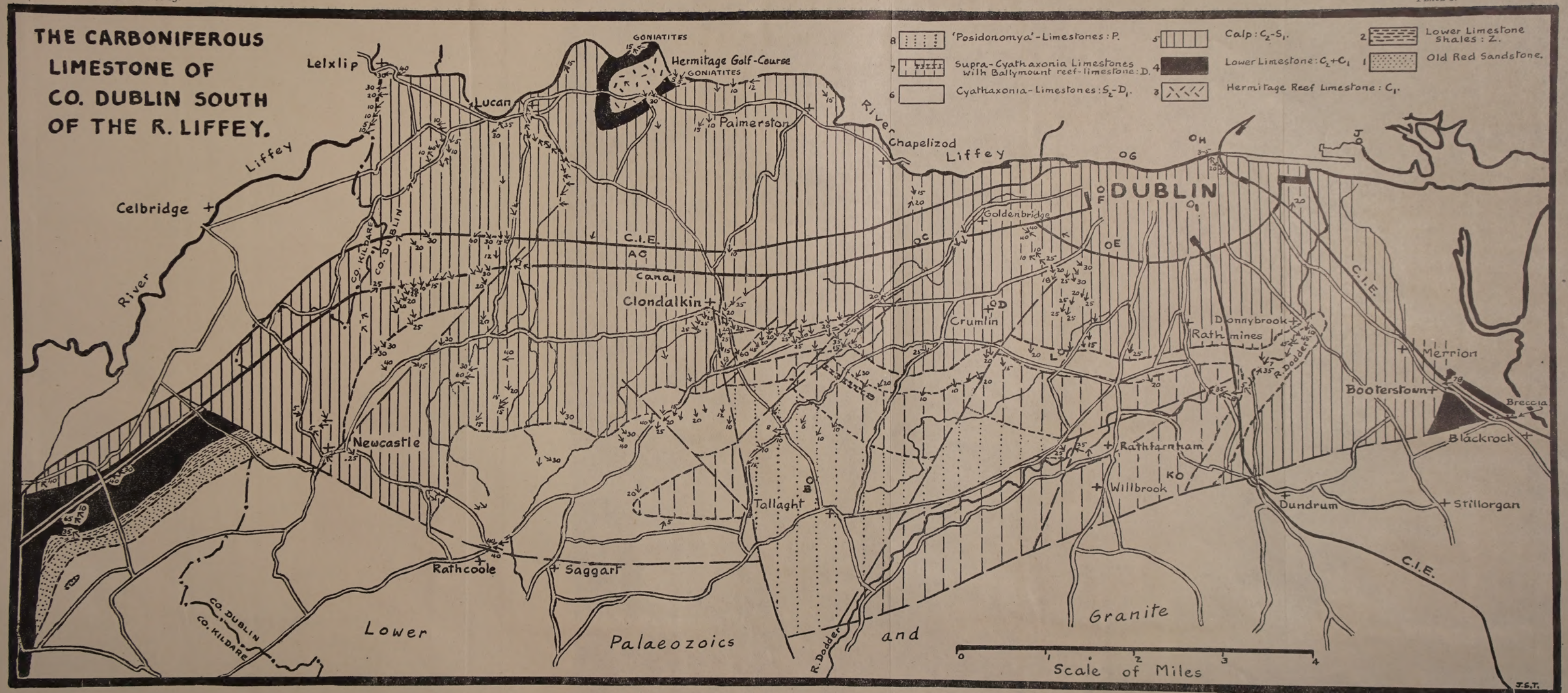
Plate 6.

Geological Map of the Carboniferous Limestones south of the River Liffey, Co. Dublin. Scale, one-inch to a mile. The map is oriented north-south and east-west, but owing to the projection employed, the eastern margin bears 1° east of north. Wells: A, Clonbarris Cottage, Clondalkin (p. 175); B, Urney Chocolate Factory, Tallaght (p. 186); C, Inchicore Transformer Station, Goldenbridge (p. 174); D, Crumlin Park Athletic Ground (p. 174); E, Clarke's Factory, South Circular Rd. (p. 174); F, Guinness's Brewery, St. James's (p. 174); G, Judd Bros', Hendrick Street (p. 174); H, Thwaites's Factory, O'Connell Street Upper (Lamplugh and Others, 1903, p. 88); I, Ovendon and Orrs' Factory, St. Stephen's Green (*ib*, p. 88); J, Dublin Port Milling Co., Alexandra Quay (p. 174); K, Hazelbank Farm, Rathfarnham (p. 187); L, Dublin Dairies, Kimmage (p. 175).

A

B

C



Based on the Ordnance Survey by permission of the Minister for Finance.